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How Floaters Respond To Subsea Blowouts

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Common wisdom in the oil industry suggests that floating drilling vessels will sink suddenly if a subsea blowout occurs beneath them. Well-control schools and texts on floating drilling often describe how the gas bubbles "aerate" the water and rob the vessel of buoyant support.

This belief is completely false. Recent technical studies clearly demonstrate that the actual loss of buoyancy in a blowout is quite small for all believable well rates and reasonable water depths.

No one will deny that a blowout offshore (or anywhere) is a dangerous situation that requires prompt and decisive action. The notion that the drilling vessel is about to disappear beneath the surface can only add to an atmosphere of panic and invite critical mistakes. This misconception also may cloud policy decisions on such matters as riserless drilling and wellcontrol.

Technical Study

The Massachusetts Institute of Technology Department of Ocean Engineering recently investigated this controversial subject.[1] The study included a survey of actual blowout incidents involving floaters, development of a computer model of a vessel in a blowout, and large-scale experiments with a floating object in a bubble plume.

Research focused on vessel response, and did not address the risk of fire and explosion, an ever-present danger in any blowout. Conoco Inc. and Gulf Oil Corp. jointly funded the effort, which built on previous work supported by Exxon Corp. The experimental program was sponsored by the U.S. Navy and the Department of the Interior.

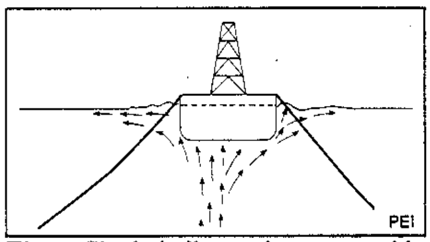

Fig. 1. Single-hull vessels are unstable over the center of a blowout, but the actual loss of buoyancy is quite small.

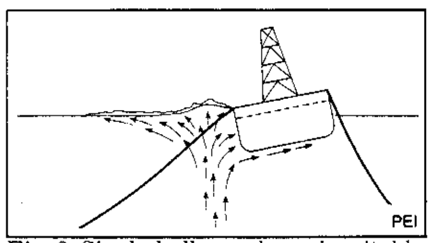

Fig. 2. Single-hull vessels are inevitably pushed to one side by blowout plumes, and mooring lines can cause them to heel into the plume.

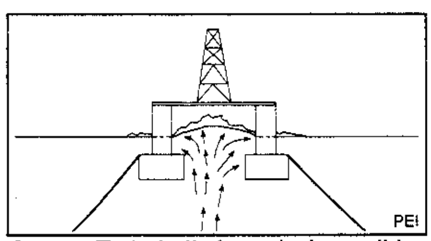

Fig. 3. Twin-hulled semisubmersibles are naturally centered over blowouts, and their low-placed moorings cause little heel.

Actual Incidents

Actual blowout situations were surveyed extensively. The researchers studied public reports and interviewed company and contractor personnel. To encourage free discussion, it was agreed to report only general trends, not particular accidents by location, rig name, or company.

The survey encompassed 11 incidents – eight involving barge or ship types and three with semisubmersibles. Major conclusions were:

- In all cases where the vessel sank (about one-third of the incidents), the sinking could not be related to density reduction in the plume. Instead, hull damage due to explosion and downflooding of open compartments were the major factors.
- Some apparent loss of freeboard and a definite list or heel angle into the boil were observed in most cases, especially on ships or barges. A few situations included a report of an increase in freeboard.
- Low freeboard ships or barges were most prone to sinking. They experienced large amounts of water on deck. This effect was not observed on semisubmersibles.

Further study of blowout characteristics revealed a mechanism that explains the dramatic effect of a blowout on a ship or barge. Fig. 1 shows how the single-hull vessel is unstable over the center of the blowout. Inevitably, it will be pushed to one side (Fig. 2). Then, the mooring lines at the main deck will hold it against the outflowing current from the blowout and cause it to heel into the plume. In this position, water can come over the side – and jet up the moonpool – to fill any open or damaged compartments.

In contrast, the twin-hulled semisubmersible (Fig. 3) is naturally centered over the blowout, and its low-placed moorings cause little heel. Two key actions will prevent sinking on a ship-shaped vessel: (1) close all watertight doors so compartmentation of the ship will help keep it afloat even if some downflooding occurs, and (2) if possible, release the mooring lines so the vessel will return to an upright position and drift away from the blowout.

Plume Characteristics

Building on insights from actual incidents, a theoretical model for the steady-state behavior of a vessel in a blowout was developed. Previous MIT work on characteristics of a blowout plume provided a starting point.

When a subsea blowout occurs, the escaping gas forms a bubble plume above the surface. The gas bubbles entrain water in a turbulent rising plume. As this rising plume approaches the sea surface, the flow direction changes from generally vertical to generally horizontal, with radial flow away from the plume center. The upwelling water raises the surface into the form of a mound over the center of the plume. Because gas is mixed with the water, the average fluid density is less than that of pure water.

Furthermore, the violent turbulence at the top of the central boil creates a foam which floats on top of the bulk flow. Because of all these features, a floating vessel encounters markedly altered hydrodynamic conditions in a blowout.

All plume properties are reckoned with respect to the centerline of the plume. This centerline does not remain at a fixed location, however. Bubble plumes are laterally unstable due to their highly turbulent nature. Random lateral motions that occur are roughly the same magnitude as the plume diameter.

This diameter increases as the plume rises. For practical purposes, it may be approximated as a cone with about a 10° included angle. The time scale for observed plume motions is long – 15 to 90 sec in one 200-ft water depth case.

Fig. 4 shows some of the main features of a blowout plume, including surface behavior, typical density changes, and upwelling water flow. Results from calculations and experiments provide a feel for some of these parameters.

For example, in a 50 MMscfd blowout in 400 ft of water, the density reduction on the centerline of the plume near the surface is only about 4%. For the same plume in 100 ft of water, the reduction of density would reach 16%. Typical upwelling water velocities range between 1 and 20 ft/sec. For the 50 MMscfd plume in 400 ft of water, the upward velocity would reach 6 ft/sec. Outflowing water speeds at the surface are typically comparable to the upwelling value.

Vessel Response

Using the model of plume behavior described previously, a computer program was prepared to calculate the steady forces and moments imposed on a vessel at a specific location to the plume centerline.

This model accounts for the upwelling and outflowing currents, surface level changes, and density variation. It assumes that the vessel exerts little influence on the plume characteristics. Along with stability and mooring constraints, the program can be applied iteratively to predict the mean position of a vessel in a blowout.

Sample calculations were performed to exercise the model and reach some conclusions about the blowout response of some candidate floating production vessels, including semisubmersibles and tension-leg platforms. Sample cases included:

- A 45,000-ton TLP, in 600 ft of water, with blowout rates of 30 and 60 MMscfd.
- The same 45,000-ton TLP, in 2,400 ft of water, with a blowout rate of 30 MMscfd.
- A 75,000-ton TLP, in 600 ft of water, with a blowout rate of 30 MMscfd.
- A 24,000-ton semisubmersible, in 600 ft of water, with a blowout rate of 30 MMscfd.

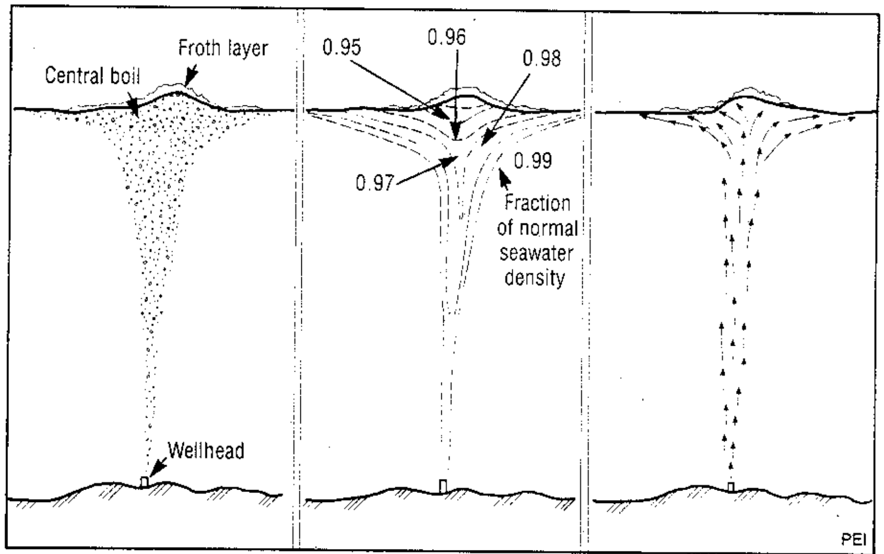

Fig. 4. Main features of a blowout plume include (left) its form, (center) the altered density field, and (right) entrained water velocities.

Results showed that the expected vertical force change was small for all cases. A maximum steady reduction of 300 to 400 tons was predicted in a position directly over the plume. For the TLPs, this force change would be negligible compared to the mooring tensions; for the semisubmersible, a 3 to 4 ft loss of freeboard would result. Thus, the steady vertical force responses are small.

On the other hand, the net horizontal forces on these rigs can grow relatively large if they are displaced away from the plume center. For the small TLP in 2,400 ft of water, the horizontal force reached about 150 tons. This would be equivalent to the force caused by a 60- or 70-knot wind – well within the mooring capability, but still impressive.

It should be stressed that the quasi-steady forces and responses discussed above could be augmented by dynamic fluctuations. The fluctuations are bound to occur as a result of the unsteady wandering of the plume.

If plume oscillations match the dynamic response period of the rig – vertically or horizontally – the rig responses could briefly reach values considerably above or below the steady-state response prediction. This effect was observed in the experiments described next.

Plume Experiments

Experiments also were performed with air bubble plumes in 175 ft of water. The experiments focused on obtaining large-scale data on plume characteristics. The opportunity presented itself, however, to observe the effect of these plumes on a floating object.

Fig. 5 shows the test setup at a U.S. Navy facility in Bugg Spring, a sinkhole near Okahumpka, Fla. The floating object used in the test (Fig. 6) was not intended to model any particular rig. Due to handling considerations, it had to be much smaller than an accurately scaled rig model would have been.

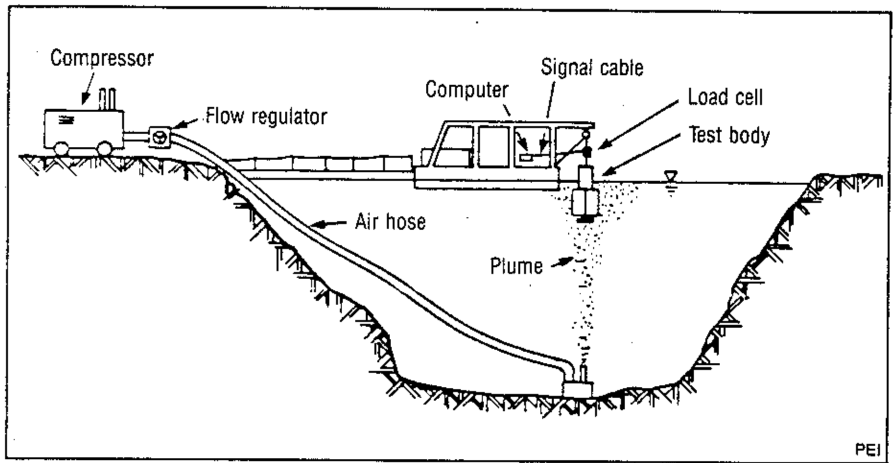

Fig. 5. Equipment arrangement for the plume simulation tests at Bugg Spring, Fla.

Forces were measured while the test body was vertically and horizontally restrained. Then the test body motions were observed while the body was left free to move vertically.

It was seen, first of all, that the test body did not sink, despite the fact that it was small in relation to the plume. The force changes on the fully restrained body were modest. A maximum force of about 50 lb upward was observed. This is small in comparison to the total weight of about 1,700 lb and would cause a 10% increase in freeboard.

When the vertical restraint was released, though, the body oscillated vertically and showed fluctuating (up and down) freeboard changes several times the 10% predicted from the restrained force measurements. This was clearly a result of dynamic amplification, and points to a need to consider plume dynamics for unrestrained floating vessels.

What It Means

The MIT work on the behavior of vessels in a blowout gave consideration to actual incidents, theory, and large-scale experiments. It provided the following insights:

- A dramatic flotation loss due to "aeration" of the water around a rig is not possible for believable blowout rates in any reasonable water depth. Actually, the average vertical support force changes very little in a blowout. A net upward force may even result if the upwelling water flow overcomes the slight loss of fluid density due to the bubbles.
- Blowout plumes can generate large outflow currents which may cause a ship or barge-type rig to

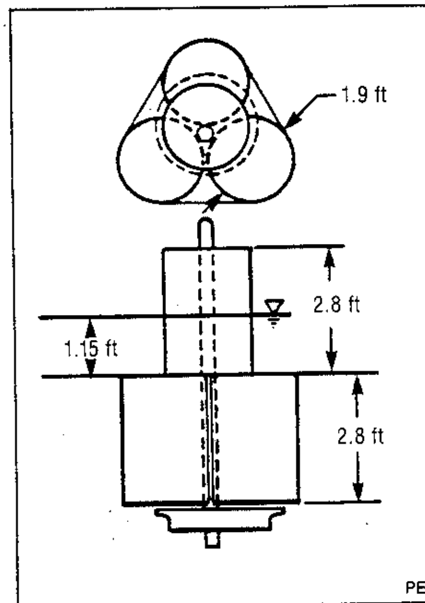

Fig. 6. Two views of the test body used during the Bugg Spring trials. Weight was provided by the railroad wheel at the bottom.

heel into the blowout as the mooring restraint acts at deck level. Large quantities of water then may be carried onto the deck. This may result in downflooding of open or damaged compartments and sinking of the rig – after several hours or even days.
- The unsteady nature of a blowout plume can lead to fluctuating dynamic forces on a rig. These fluctuations may occur at a frequency that excites a dynamic response of the rig. If so, oscillations may result and these are likely to be considerably larger than the steady predictions. This effect is not expected to cause the rig to sink. It should be considered, however, when predicting an expected response to a blowout.

These key points can help to focus the thinking of those involved with floating drilling. The knowledge that the rig will not "sink like a rock" seconds after a blowout should help broaden the scope of available remedial action. There will be time to close all the compartments and either control the blowout or release the moorings and move away.

References

1. Milgram, Jerome H. and McLaren, W. G.: *The Response of Floating Platforms to Subsea Blowouts*, MIT Department of Ocean Engineering, Report No. 82-8 (July 1982).